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Distribution Modeling:
It's not just the grid anymore!

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GridLAB-D™:
A Unique Tool to Design the Smart Grid

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Unifies models of the key elements of a smart grid:

Power Systems ***Loads*** ***Markets***

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Over 90,000 downloads in over 150 countries

- ✓ Smart grid analyses
  - field projects
  - technologies
  - control strategies
  - cost/benefits
- ✓ Time scale: sec. to years
- ✓ Open source
- ✓ Contributions from
  - government
  - industry
  - academia
- ✓ Vendors can add or extract own modules

Typical Use Cases

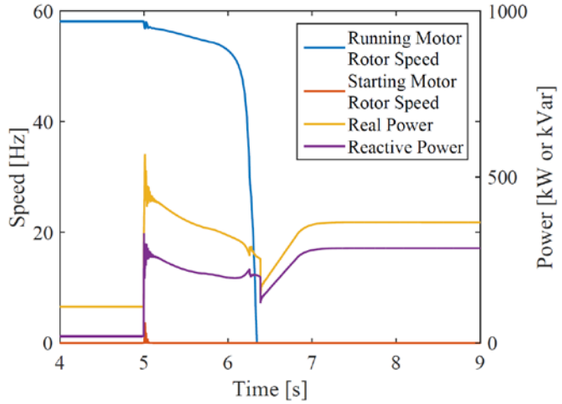
- Interconnection of distributed generation and storage
- New and innovative retail market structures (e.g., DSOs)
- Evaluation of demand response and energy efficiency
- Volt-VAr optimization and CVR design
- Evaluation of distributed or decentralized control behaviors
- Sectionalizing, reconfiguration, automation, and restoration
- Microgrids and resiliency

- Open-source, time-series simulation of an operating smart grid, from the substation to individual end-use loads and distributed energy resources, in unprecedented detail
- Simultaneously solves 1) power flow, 2) end-use load behavior in tens of thousands of buildings and devices, 3) retail and/or transactive markets, and 4) control system behaviors

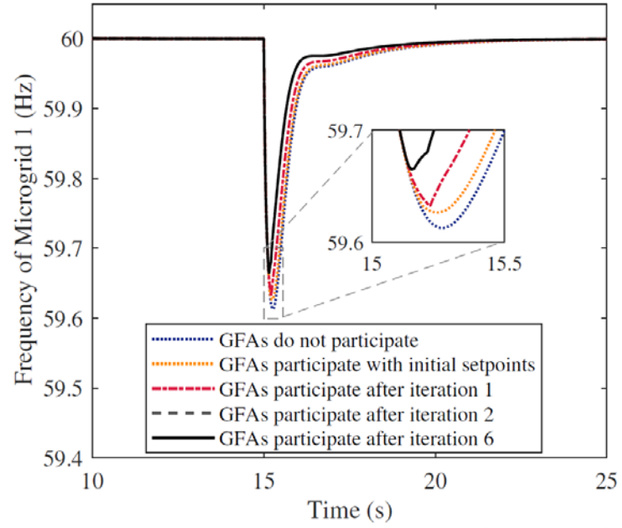
Microgrids

- Examine use of microgrids for improving resilience
  - Critical load-serving assets for single resource, community-level microgrids, or blackstart resources
  - Usage of existing assets and controls to maintain (or improve) transient stability
  - Impact of centralized control over traditional, distributed controls

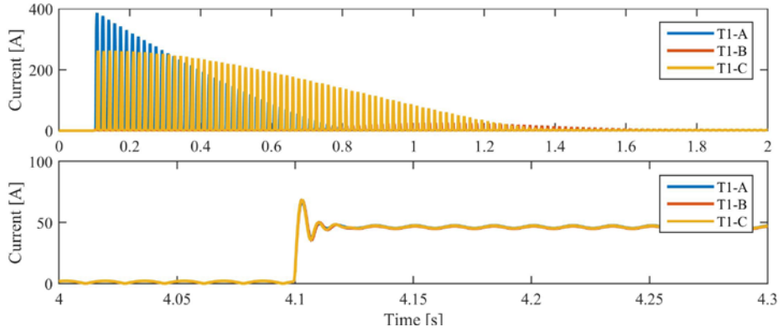
- Requirements to study the aspects of islanded, low-inertia systems
  - Feeder-level system studies, including multiple microgrids as independent or networked resources
  - Three-phase unbalanced electromechanical dynamic models of DERs and DG
  - In-rush associated with load pickup and transformer saturation
  - Interconnection standard impacts, such as IEEE 1547 on inverters
  - CVR-effect-based controls to use load to mitigate frequency transients



Power measurements at a running motor and starting motor on simple 4-node system [1]



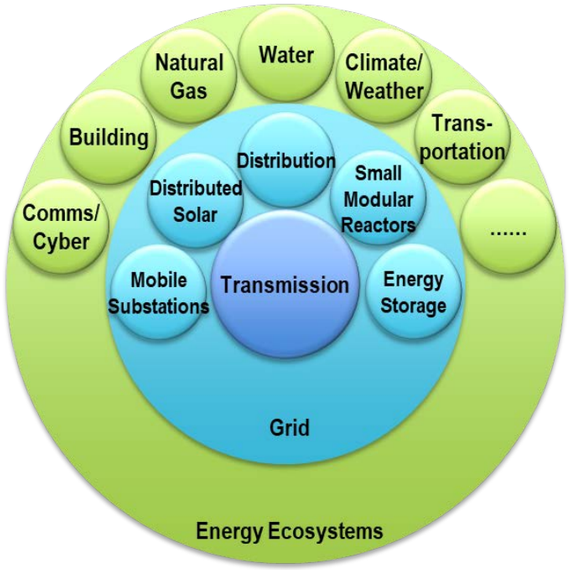
Load participation in managing microgrid frequency [2]

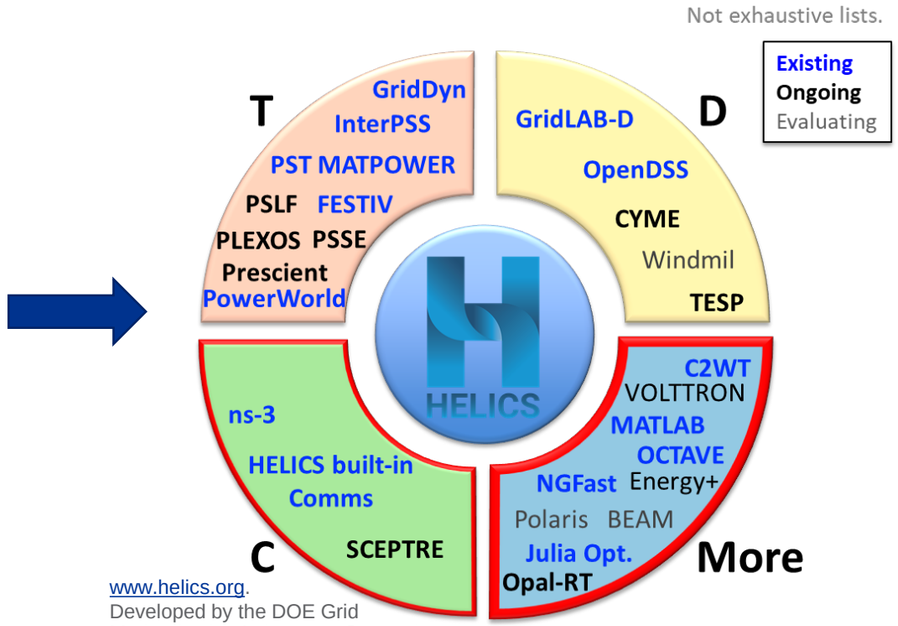


Transformer current in 8500-node system during connection of primary transformer [3]

Co-Simulation of Multiple Domains

- There is increasing interdependence between critical energy infrastructures – Natural Gas and Grid, Telecommunications and Grid, Distribution and Transmission, Buildings/DERs and Grid, EVs and Grid, etc.
- Comprehensive system analysis is necessary to understand the relationships, dependencies, constraints, and joint evolution of these interconnected systems.
- Co-simulation is only *one* approach that leverages existing tools, data, and models; however, it may not be the right approach further down the road.





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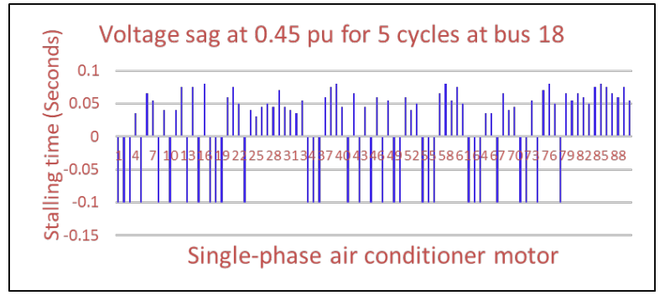
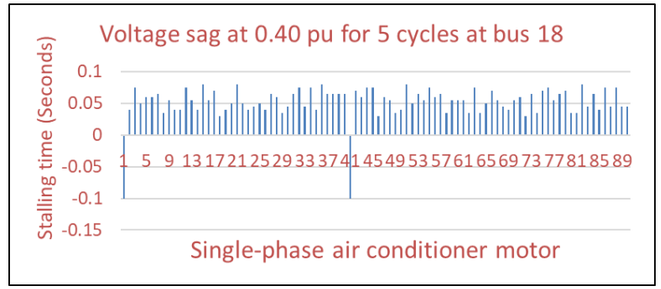
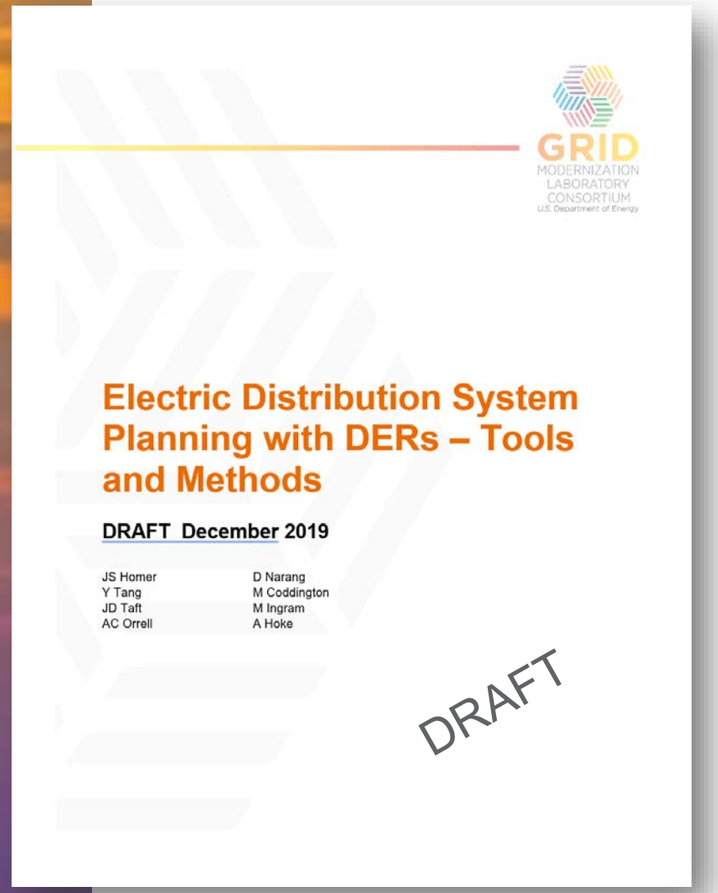
Developed by the DOE Grid Modernization Laboratory Consortium.





Example of co-simulated Transmission and Distribution system and the impact of diverse distribution voltages on HVAC stalling characteristics. Source: PNNL.

Near Term Needs with Respect to DERs



- To remain flexible and adaptable to changing conditions and technology development, scenario analysis, granular forecasting, and options analysis are becoming increasingly important in integrated distribution system planning.
- Utilities need accurate, granular data to develop system models, validate results, and perform analysis. It is essential that utilities and regulators prioritize strategic, targeted data collection; identify data gaps; and develop strategies for filling data gaps.
- While there are emerging tools that can provide utilities with granular load and DER forecasts, a tool capable of evaluating different DER deployment scenarios and policies and then automatically updating projections based on actual deployment patterns would be helpful for utility planners and regulators.
- Several tools are needed that could assist utility planner, including commercial tools, that move beyond hosting capacity screens and automatically generate solutions when hosting capacity or interconnection analyses identify an issue.
- More robust tools are needed that can simulate distribution systems with multiple devices, such as smart inverters and energy storage, simultaneously operating autonomously or in coordination.
- Engineering tools that incorporate power flow analysis are needed for selecting optimum type, sizing, and placement of DERs at the distribution system scale.

Future Recommendations

- Include electromechanical and electromagnetic simulation capabilities that capture inverter, DER, and microgrid controls (among others)
- Improve behind-the-meter representations for buildings, loads, DERs, etc.; including various control settings and designs and at various time resolutions
- Transition from hosting capacity tools to integrated planning tools, which can represent all new technologies in a holistic manner, spanning optimization to engineering based decisions
- Enhance multi-domain modeling to represent the interdependency of energy systems, including T+D, D+Comms, D+Markets, D+transportation, etc.
- Move away from deterministic solutions to probabilistic or risk-based modeling
- Address information and data gaps particularly around consumer response, interactions with new technologies, and forecasting of adoption rates

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Thank you

Sources

[1] https://doi.org/10.1109/TSG.2018.2809452

[2] Under review, “Learning-Based Load Control to Support Resilient Networked Microgrid Operations”, Nikitha Radhakrishnan, Kevin Schneider, Francis Tuffner, Wei Du, Bishnu Bhattarai, IET Smart Grid, Manuscript reference: STG-2019-0303

[3] https://doi.org/10.1109/TPWRS.2016.2548880

[4] Under review, “Electric Distribution System Planning with DERs – Tools and Methods”, JS Homer, Y Tang, JD Taft, AC Orrell, D Narang, M Coddington, M Ingram, A Hoke, Draft DOE Report, Dec. 2019

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